The University of New Mexico Bulletin

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CHEMICAL AND BIOLOGICAL STUDIES OF THE WATERS OF ELEPHANT BUTTE RESERVOIR AS RELATED TO FISH CULTURE

A Summary of Researches Made by Various Investigators

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THE UNIVERSITY OF NEW MEXICO BULLETIN
Whole Number 330 August 15, 1938
Chemistry Series, Volume 2, No. 6

Published monthly in January, March, May, July, September, and November, and semi-monthly in February, April, June, August, October, and December by the University of New Mexico, Albuquerque, New Mexico

Entered as Second Class Matter, May 1, 1906, at the post office at Albuquerque, New Mexico, under Act of Congress of July 16, 1894

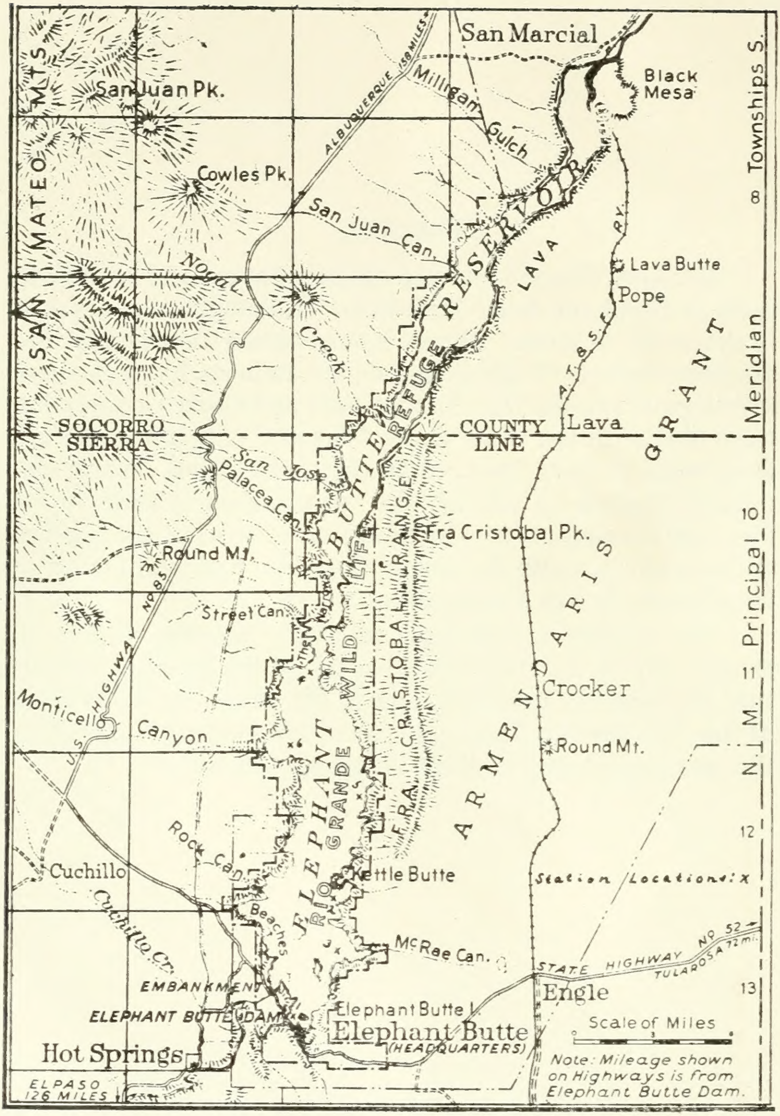
UNIVERSITY OF NEW MEXICO PRESS
1938

FOREWORD

Hazzard, Greenbank, and Barker have made investigations at Elephant Butte Reservoir. Kalmbach has assisted in the study of birds. Sperry looked rather thoroughly into the depredations of fish-eating ducks. Reports from all these investigators to the New Mexico Fish and Game Commission were filed with the State Game Warden. All the investigations were, in part, financed by the Commission. The Commission desired to publish the information resting in its files, and the author, who had assisted in some of the studies, volunteered to write the report from the material placed at his disposal by the Commission.

The author is indebted to State Warden Elliott S. Barker, Dr. A. S. Hazzard, Director of the Michigan Institute of Fisheries Research, and to Mr. Hugh B. Woodward, of the New Mexico Fish and Game Commission, for reading the manuscript and making valuable suggestions.

J. D. C.



Map of Elephant Butte Reservoir

Biological and chemical sampling stations shown with X. U. S. Highway 85 now runs much closer to the lake than is shown on the map.

CHEMICAL AND BIOLOGICAL STUDIES OF THE WATERS OF ELEPHANT BUTTE RESERVOIR AS RELATED TO FISH CULTURE

INTRODUCTION

Since the beginning of the present century, many examinations have been made of streams, lakes, and reservoirs of the United States, seeking to discover conditions existing in those waters, and with knowledge of such, to find means of improving these conditions for fish culture. Such studies are included in the science of Limnology,[1] and while it refers to all inland waters, particularly does it refer to lakes.

The results of studies already made have been of invaluable assistance to the departments of fish and game in the states in which waters are located and, because of the known value of such studies, the Department of Fish and Game of the State of New Mexico, and the U. S. Bureau of Fisheries, in June and in July of 1935, jointly conducted a preliminary fisheries survey of the waters of the Elephant Butte Reservoir. The work was done by A. S. Hazzard,[2] then associate biologist for the Bureau, assisted by James Moffett, Roy E. Barker, and John Greenbank. The author gave some assistance at the time the work was initiated.

The purpose of the preliminary survey was to determine, in so far as possible in the limited time available, the general suitability of the waters of the reservoir for fish life and to make recommendations for future fish cultural policy. At the conclusion of this study Dr. Hazzard filed a thirty-five page report,[3] which included many tables, graphs, and maps, with the Department of Fish and Game in Santa Fe.

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[1] Welch, Paul S., *Limnology*, McGraw-Hill Book Co., New York, 1935, is an outstanding book, of interest to fishermen with biological training.

[2] Director of the Michigan Institute for Fisheries Research.

[3] Hazzard, A. S., "Preliminary Fisheries Survey of Elephant Butte Reservoir, New Mexico," 1935 (mms).

It was felt that this preliminary survey did not cover a sufficiently long period of time to show seasonal variation in many factors studied. At a conference between State Game Warden Elliot S. Barker and the author, arrangements were made between the University of New Mexico and the State Department of Fish and Game whereby the studies might be continued for a year as joint research projects, the expenses being paid by the Department of Fish and Game. John Greenbank, now a fisheries technician with the Institute of Fisheries Research of Michigan, and Roy E. Barker did the field work with supervision from the Department of Fish and Game, and the author, from the Department of Chemistry, and Dr. Willis H. Bell, from the Department of Biology, in the University. The continuation of the investigation along these lines was recommended in the original report. The results of a year's work are compiled in two reports, one by John Greenbank,[4] and the other by Roy E. Barker.[5]

While much in the reports of the studies already made is technical in character, there is, nevertheless, a great deal of information of value and of interest to the average citizen; and which, moreover, has an unusual appeal to the sportsman. Because of these facts this bulletin has been prepared in order that the information already secured may be available to anyone interested in the topic under consideration, in a publication only slightly technical in character, which, it is hoped, gives the outstanding interesting facts concerning these waters without including much of a technical nature. If material of the latter nature is desired it can still be obtained from the original sources from which this bulletin has been prepared. The expense of publication has been shared by the Department of Fish and Game and the University of New Mexico.

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[4] Greenbank, John, "A Chemical and Biological Study of the Elephant Butte Reservoir as Related to Fish Culture," master's thesis on file in the library in the University of New Mexico, 1937, 102 pp.

[5] Barker, Roy E., "A Report of a Chemical and Biological Survey of Elephant Butte Reservoir," on file with the Department of Fish and Game, Santa Fe, New Mexico, 1937, 60 pp.

FISHERIES STUDIES IN NEW MEXICO

During the past twenty years, sporadic fisheries studies have been made at various times in New Mexico. These investigations were, for the most part, rather brief and casual and often were concerned with such matters as the welfare of fish at the state hatcheries.

In the summer of 1934, the United States Bureau of Fisheries[6] made a survey of the principal streams and lakes of the Carson and the Santa Fe National Forest in New Mexico. The canals of the middle Rio Grande Valley have been studied by Shettles,[7] and again from a chemical standpoint by Hillard L. Smith and the author,[8] a study which proved the drainage canals of the middle Rio Grande to be adapted for the growing of trout. Both studies were sponsored by the New Mexico Department of Fish and Game, the work being done in coöperation with the University of New Mexico. A study in fish mortality was made by Clark and Greenbank.[9] Several other small lakes in New Mexico have been studied in recent years, and stream conditions are constantly being ascertained and improved by the United States Forest Service. The better informed sportsman has become thoroughly convinced that scientific studies of waters lead to greatly increased production of desirable fishes.

THE ELEPHANT BUTTE RESERVOIR

The Elephant Butte Reservoir, formed by the Elephant Butte Dam, a United States reclamation project, was begun in 1911, and began to fill with water in 1914. The reservoir impounds the entire flow of the Rio Grande, and when full extends a little over forty miles nearly north and south, having an area of over 39,000 acres. The region lies wholly in the lower Sonoran Zone, which is characterized by the semi-desert flora of the piñon, juniper, cactus, mesquite, etc. When the reservoir is full, extensive shallows exist at the north end. At the south, shores are precipitous, but become more gentle as they go northward. The east side, having fewer shoals, is more precipitous than the west. The shore line at the east side is predominantly of rock and gravel, in contrast to the gently sloping shore line of the west side, which contains considerable areas of sandy silt with fewer rocky ledges. Many small side canyons are flooded with water when the reservoir is at its higher levels. These, with their steep walls, often of columnar basalt, are very beautiful.

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[6] Gersbacher, W. M., "A Survey of the Waters of the Santa Fe and Carson National Forest, New Mexico," Washington, U. S. Bureau of Fisheries, Mimeographed, 1935, 38 pp.

[7] Shettles, L. B., "Some Biological Aspects of Fish Culture in the Middle Rio Grande Conservancy Drains," a master's thesis on file in the library of the University of New Mexico, 1934, 27 pp.

[8] Clark, John D., and Hillard L. Smith, "A Chemical Study of the Waters of the Middle Rio Grande Conservancy as Related to Fish Culture," *University of New Mexico Bulletin* No. 270, July 15, 1935, 36 pp.

[9] Clark, John D., and John Greenbank, "A Cause of the Death of Fish in the Southwest," *University of New Mexico Bulletin* No. 294, September 15, 1936, 22 pp.

Being located close to United States Highway No. 85, the principal north and south highway through New Mexico, and being within a few hours' drive of several large cities, the lake has become popular as a recreational area for boating, swimming, and fishing.

THE FISH IN ELEPHANT BUTTE RESERVOIR

Since this bulletin has been prepared from the much more technical and much more extensive reports made at different times by Hazzard, Barker, Greenbank, Kalmbach and Sperry, for the average man interested in fishing, an enumeration of the fish population of the lake is deserving of a place at the beginning of this work. In the Elephant Butte Reservoir there are at least twelve species of fish, some of which are native to the waters and some of which have been introduced by stocking. These are enumerated as follows:

1. Large-mouth black bass, *Huro flordana* (LeSueur) (formerly *Micropterus salmoides).*—The large-mouth bass is one of the best known, and one of the most desirable, warm water fish in North America. It usually is very gamy, taking many kinds of lures. However, it has slack periods of biting in this region, particularly in the heat of midsummer.

It is almost strictly carnivorous, and is quite cannibalistic. The food of the adult consists almost entirely of fish, sometimes of its own kind. Bass weighing well over ten pounds have been taken from the lake. Barker, as a result of his biological studies, states that the bass in the lake average between three and four pounds in weight.

2. White crappie, *Pomoxis annularis* (Rafinesque). —The crappie is another game fish of the same family (the sunfish family). Although it is a fairly good game fish and food fish, it does not enjoy the prestige of the bass, probably because of its considerably smaller size. It is largely carnivorous, and although it may feed occasionally upon vegetation, it usually prefers a diet of live fish.

3. Yellow perch or ring perch, *Perca flavescens* (Mitchell).—The perch is rather less gamy, and often much easier to catch, than bass or crappie. It is considered a good food fish. Its food is variable, and includes fish, insects, and vegetation.

4. Blue catfish, *Ictalurus furcatus* (LeSueur).—The blue catfish is esteemed more as a food fish than as a game fish, often being taken with still bait or on set lines. It is rather omnivorous in feeding habits, eating dead fish or other dead animal material, insects, and vegetation.

5. Yellow catfish or mud catfish, *Opladelus olivaris* (Rafinesque).—The yellow catfish differs from the blue catfish by not having a forked tail fin and by its (olive) color. Its food habits probably are similar to those of the blue catfish.

6. Channel catfish, *Ictalurus punctatus* (Rafinesque). —The channel or spotted cat is a trimmer, more active fish than any of the related species. It lives in clearer waters and has a cleaner diet. These catfish are plentiful in Elephant Butte Lake and may be caught on trot lines and bait at the upper end of the lake. Some New Mexico sportsmen have taken very large specimens (up to forty pounds) with slow moving, deep running, bass plugs.

7. Blue gill sunfish, *Helioperca incisor* (Cuvier and Valenciennes).—The blue gill is a small fish, usually not over six to ten inches in length. Hence, although it is a pretty fish, it is not very important to the fisherman in this reservoir. It feeds upon insects and small animal forms, and upon vegetation.

8. Gizzard shad, *Dorosoma cepedianum* (LeSueur).—The gizzard shad (so-called because it possesses a digestive organ that resembles a gizzard) is not considered a good game or food fish, since it is small and very bony. However, it is of immense value in providing forage for the game fishes. It feeds upon the bottom to a great extent, consuming mud and debris (from which it obtains some food material), insects and vegetation. It also is well adapted, by reason of its many gill-rakers, to the utilization of plankton, which it strains out of the large volume of water that passes over its gills.

9. European carp, *Cyrinus carpio* (Linnaeus).—The carp ordinarily is despised by fishermen as being of no value for sport and of very little use for food. It feeds upon mud, vegetation, and sometimes dead fish or fish remains. Its young furnish a certain amount of food for game fish.

10. Small-mouth buffalo, *Ictiobus bubalus* (Rafinesque).—The buffalo has habits similar to those of the carp. It closely resembles the carp in appearance, the chief superficial difference being the lack of the barble at the jaw which is possessed by the carp.

11. Carp sucker, *Carpiodes sp.*—The carp sucker is related to the buffalo, and has much the same appearance, except that its lips are not folded (as are those of the buffalo) and that it has a silvery appearance. It also feeds upon mud, algae, and vegetation. It provides some forage for game fish.

12. Mosquito minnow, *Gambusia patruelis* (Baird and Girard).—The mosquito minnow is a small fish, from one to two inches in length. It feeds chiefly at the surface,

upon the eggs and larvae of mosquitoes and other insects. It is oviparous, the young being hatched inside the body cavity and born alive. It is hardy, and is rather prolific.

Salmon and Trout

Some years ago salmon and trout were planted in the reservoir. It is reported that some of these fish were taken within the first year after they were planted. These, however, did not seem to be in good condition. Since that time, few, if any, have been caught from the lake.[10] Certainly, none of them was taken by the different netting processes carried on by the various surveys, and netting has been extensive.

Immediately below the Elephant Butte dam, trout find the water apparently entirely satisfactory. The author has seen trout in some of the deep pools which probably would weigh six or eight pounds, and in the shallows has seen tiny fingerlings in great numbers. There seems to be little question that the failure of trout to live in the lake (while they thrive in the river immediately below the dam), is to be found in the fact that the colder bottom water from the lake picks up a content of oxygen necessary for the respiration of trout, as it emerges with great violence against the rocks below the dam.

CHEMICAL NATURE OF THE WATER

In order that water may be suitable for the growth of fish it must contain no outstanding contamination, either organic or inorganic in nature, and research has shown little of either in the water of the reservoir.

Oxygen

The water must, at all times, contain a sufficient amount of oxygen to sustain respiration. The amount of oxygen dissolved in water increases as the water gets colder and decreases as it gets warmer. Furthermore there is a decrease in the amount of dissolved oxygen in all waters in late summer or early fall, when organic material from plants begins to decay, and in its disintegration, consumes a great deal of dissolved oxygen. Oxygen may be added to the water by the action of wind and wave, by inflowing water, or by growing plants which, during their growth, take in dissolved carbon dioxide, retaining the carbon and putting oxygen back into the water. It is definitely known that, as water temperatures increase, fish grow at an accelerated rate and thus with warmer water the requirements for dissolved oxygen increase. Studies of the oxygen content of the waters of the reservoir show that, at all times of the year, such dissolved oxygen is always present in the upper layers of water but that in the late summer and early fall, the lower and colder layers of water are far too low in oxygen to support fish, and, in all probability, the disappearance of salmon and the trout from the waters of the lake can be attributed to the fact that if these fish remain at depths where the temperature would enable them to survive (they being cold water fish), they would suffocate, and if they rise to levels of satisfactory oxygen content they must try to live in an environment too warm for them to survive. In order not to burden the reader with a large amount of tabulation at this point, the oxygen content of the water at various depths and at different times, together with other data, has, in chart form, been placed in an appendix. By careful study of the charts and curves in the Appendix, one may find proof for the statements made in the text.

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[10] Mr. Hugh Boyd, Federal and State Fish and Game Warden at the lake, reports that several trout were taken in the spring of 1938. All were in poor condition. He thinks that they came down the river from the clear water drainage canals further north. These canals now are well stocked with trout.

Dissolved Free Carbon Dioxide

Carbon dioxide is a product of respiration, decay, and combustion. It is a gas soluble in water. Just as an overabundance of carbon dioxide and a deficiency in oxygen can suffocate land animals, so can these conditions cause death of fish. The higher the temperature the more severe is the presence of a large amount of carbon dioxide. Green plants secure their carbon from this gas, the land plants taking the gas from the air, and aquatic plants from the gas which has dissolved in water. Studies made at Elephant Butte reveal no excess carbon dioxide in the water at any time during the year. Those interested in this will find details in the Appendix (Table III).

Carbonates and Bicarbonates

Ordinarily, dissolved carbonates and bicarbonates are without harmful effect on fish and other organisms unless the amounts become excessive. They are never excessive in the waters of Elephant Butte Reservoir, as will be seen in detail in the Appendix (Table III).

Acidity and Alkalinity

Waters vary greatly from place to place and from time to time in their acidity and alkalinity. To give expression to these conditions the scientists have devised a scale upon which pH 7 indicates strict neutrality, with acidity becoming stronger as the figure behind the pH goes from 7 downward, and progressively more alkaline as the figure behind the pH goes from 7 upward. Fish of most species are generally tolerant of a large range in values of pH. Studies made at the lake reveal that the waters range from neutrality to very slight alkalinity, and are entirely favorable in this respect for supporting fish (Table III).

PHYSICAL CHARACTERISTICS OF THE WATERS

Transparency

As long as water is fairly clear and is not actually turbid, its relative transparency has little to do with fish. Many warm water fish can tolerate turbidity and some fish actually prefer it. Moreover, turbidity of the water is often caused by the presence of suspended articulate organic material which forms a source of food for certain aquatic organisms.

However, transparency of water is, in a large measure, essential for large food production of chlorophyll-bearing plankton (small organisms) which constitute an extremely important unit in the productivity of water. Plants of this group require light for their growth and light can reach them only in proportion to the clearness of the water.

The transparency of the water is measured by noting the depth at which a four-inch white disk disappears from view, as the disk is lowered. In Elephant Butte Reservoir, these depths have ranged from two inches, near the head of the lake, to seventy-four inches, near the dam, these figures being a measure of the amount of silt carried by water at these points. Over the greater part of the reservoir the transparency of the water is not unfavorable, as is indicated in detail in Graph 2 in the Appendix; however, greater transparency would result in a very much larger amount of plankton for fish food.

Temperature

One hardly needs to say that the temperature of any body of water rises in the summer and falls in winter. Graph 3 in the Appendix shows these conditions in the water of the lake. However, in any body of water of considerable depth, it is usual to find the warm water at the top and the cold water at the bottom in summer, these conditions being reversed in the winter.

Water has its greatest density at approximately 39° F. and, in consequence of this, each fall, as the waters of a lake cool, the surface waters in reaching this temperature drop to the bottom, and the less dense bottom waters rise to the top. If ice forms over the surface of the lake, it forming at 32° F., the lightest surface layer of the water freezes and ice being less dense than water, floats. As spring approaches, the ice melts, then surface water becomes warmer and more dense, dropping to the bottom displacing the less dense bottom water which rises to the surface. One can readily see how oxygen which has been taken up by the surface water gets distributed twice a year, and it can also be seen how that stratification, as the result of varying temperatures, may remain more or less constant throughout the summer and throughout the winter. As has already been mentioned, toward the close of summer, the top layers of water in the reservoir contain sufficient oxygen for fish, but are too high in temperature for the survival of cold water species, and the lower layers, while adequately cool, have been found to be deficient in oxygen.

OTHER PHYSICAL FEATURES

Reference has already been made to silt. Throughout the Southwest, where over-grazing and other misuse of land has been severe, all of the storage reservoirs are, in the course of time, doomed to become larger bodies of silt, instead of bodies of water, unless conservation of our soil receives thoroughly adequate treatment.

Soon after the Elephant Butte Reservoir was filled, it was noted that in times of great inflow from the extremely muddy Rio Puerco, turbid water flowed out at the bottom of the dam. This indicated a flow of this fine silt along the bottom. At times of flood, the amount of silt added to the reservoir has been enormous. This suspended silt not only interferes with the production of plankton (food for fish), since the depth to which light penetrates limits the range of the tiny plants which furnish the food of the animal plankton organisms, but it limits the range of certain of the better species of fish and interferes with their spawning. On the other hand, in some places its deposition, over rocky areas, has improved these areas for the production of fish food. In general, all silt *now* added to the reservoir, represents nothing but a liability.

RISING AND FALLING WATER LEVELS

Elephant Butte Dam was erected to impound water for irrigation, thus storing water in times of abundant flow and releasing the stored water when it should be needed. This being its primary function, fish culture has had to adapt itself to the adverse conditions resulting from the fluctuation of water levels. Water rising and flooding submerges and kills much vegetation, and, in falling, leaves desirable shore vegetation, which is needed to attract the insects whose larvae and nymphs furnish valuable fish food and cover for the young fish, entirely above the shore line. As water levels fluctuate, fish may establish spawning areas only to soon find such areas too deep when the water is rising, or perhaps no water at all during its fall. Hazzard recognized these conditions in the earliest studies made upon the lake and *recommended experimentation in floating bass nests which, remaining at constant distance from the surface, have shown good results in other reservoirs.*[10a] He also recommended the construction of floating brush shelter as such brush always furnishes a place for insects to lay their eggs, and waters in these regions abound in food for small fish. Also the brush offers protection to fish from their natural enemies.

This year sees the completion of the Caballo dam, roughly twenty miles below the dam at the Elephant Butte Reservoir. A hydro-electric plant is to be installed at the larger (Elephant Butte) dam. With more nearly uniform rate of release of water from the larger reservoir and a part of its storage and release function being taken by the smaller (Caballo), it seems probable that the rate of fluctuation of the water levels in the main reservoir will be retarded. This should be favorable to fish life.

BIOLOGICAL FEATURES AND THEIR EFFECTS

Plants constitute the chief primary source of food for all animals and any water deficient in plants, not only is deficient in food for insects, which in turn become food for smaller fish, these in turn being the diet for the larger ones, but the water also lacks shelter and places of habitation for insects whose larvae and nymphs furnish valuable fish food; also such water is lacking in cover or shelter for small fish. The amount of vegetation in a water being all important, it is one of the first things studied when any body of water is being appraised for its ability to produce and harbor fish. Especially designed nets, called plankton nets, are drawn through the water for the purpose of collecting the very small, free-swimming and free-floating plants and animals. Studies made at Elephant Butte Reservoir reveal a scarcity of shore and shoals vegetation, which, in turn, means a scarcity of some of the types of fish food, as well as shelter for young fish and spawning fish, and that the quantity of plankton is considerably smaller than the quantity found in many other bodies of water, particularly in natural lakes; yet there is sufficient of this plankton to help to maintain a large population of gizzard shad and to provide food for many young fish of larger species. The organisms which live on the *lake bottom* are much less numerous than those on the bottoms of natural lakes. This scarcity probably constitutes the weakest link in the chain of fish food in this reservoir; in other words, a desirable fish, when extremely small, may be able to secure enough vegetable and perhaps animal food for sustenance and growth, and if he gets large, he may find plenty of food in the young of forage fishes, such as the young carp, suckers, and buffalo fish, and, of course, always in the millions of gizzard shad; however when this desirable fish is too large to eat the smallest food and yet not large enough to feed upon the young of other fishes, he finds this scarcity of tiny (but not too tiny) organisms particularly adverse to his well-being and growth. Studies seem to indicate that nothing more important could be done to increase the production of fish in the reservoir than *the construction of many large floating brush structures*. Of course the effect of this weak link is not noted as severely as it would be were not fair-sized bass, from a federal hatchery, placed in the lake each year.

[10a] Floating bass nests are described under the title of "Floating Bass Brooding Equipment," volume 64, of the "Transactions of the American Fisheries Society," 1934.

FACTORS FAVORABLE FOR THE INCREASE OF DESIRABLE FISH

During all investigations made at the lake, extensive netting of fish by means of seines or the gill nets were made, and all fish caught were examined. It was the general rule to find all fish which had attained a fair growth beyond the fingerling stage were very well fed. Measurements of bass of known age, and examination of their scales, indicated extremely rapid rate of growth, which can be accounted for by the long growing season and the abundance of forage fish. As Dr. Hazzard says, "The brightest spot in the fish food picture of Elephant Butte Lake is the great abundance of forage fish. Literally countless millions of carp, buffalo, carp suckers, and gizzard shad, hatched this spring, are found in every part of the reservoir. The warm surface water teems with them along the shores, among the drowned land weeds, and at the head of the lake among the cat-tails and rushes. Schools of from a dozen to hundreds are seen a mile or more from shore over the deepest water in the reservoir, swimming close to the surface and evidently feeding on plankton."

FACTORS PROBABLY UNFAVORABLE TO THE GROWTH OF DESIRABLE FISH

The Elephant Butte Reservoir is a federal bird refuge. On and around the waters are to be found Mexican cormorants, white pelicans, snowy herons, treganza blue herons, and gulls. At certain times of the year, great flocks of mergansers (fish ducks) remain on the lake. The author has had estimates from sportsmen of the number of mergansers in a flock, this number running into the thousands. He himself has shot many of these birds on the river below the dam, and has found in them large numbers of small trout. It has long been his personal opinion, based upon extensive observations (duck shooting below the dam, 1923-1937), that the burden of proof that the merganser is not decidedly disadvantageous to this region, rested upon those opposed to permitting extensive out-of-season shooting of this bird, on and below the lake. In general, aside from the mergansers, the birds killed by investigators studying the lake, have had in their stomachs the less desirable fish, although now and then some perch, blue gill, and, rarely, a bass was found. The most recent work done has shown that the earlier estimate of the damage by other birds than the merganser was somewhat low. While it is well known that fish-eating birds spread fish parasites and a number of the birds taken for examinations had parasites in them, it does not appear that birds living on and around the lake are at the present time seriously spreading parasites, although in some instances internal parasites have been found by the investigators in captured fish, particularly tape worms in some of the blue catfish. The loss of fish from parasites appears to be low, in keeping with this low parasite infestation.

THE MERGANSER SITUATION

In December, 1937, Hugh W. Boyd shot six mergansers. Roy Barker examined them, finding two empty, three containing crappie, and one a catfish. In April, 1937, E. R. Kalmbach, of the Food Habits Laboratory of the U. S. Biological Survey, at Denver, reported in a letter to State Game Warden Barker the results of his examination of the stomachs of twenty-five mergansers. His work showed that they had eaten:

	Percentages by Bulk		Number of Individuals
Carp	24.64	62.44% non-game fish	21.67
Gizzard Shad	37.80		65.83
Crappie	16.20	37.52% game fish	5.83
Bass	16.92		4.17
Yellow perch	2.40		0.83
Sunfish	2.00		0.83
Unidentified fish	0.04		0.84
	100.00		100.00

Charles C. Sperry,[11] of the U. S. Biological Survey, reports that 124 mergansers collected between November 19, 1937, and April 8, 1938, contained:

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[11] Sperry, Charles C., "American Mergansers vs. Game Fish in Elephant Butte Lake," June 7, 1938. An unpublished manuscript on file with the New Mexico Fish and Game Commission. Quoted with permission of the U. S. Biological Survey.

Game Fish	Percentage by Volume	Percentage by Occurrence
Bass	36.4	54.0
Crappie	12.8	18.0
Sunfish	4.4	26.0
Sub-total	53.6%	Average 66
Non-Game Fish		
Gizzard Shad	32.3	56.0
Carp	14.1	40.0
Sub-total	46.4%	Average 72
Total	100.0%	

When fifty-six stomachs collected from the lower part of the lake were compared with fifty collected at the upper part of the lake, it was found:

	Lower Lake		Upper Lake	
Game Fish	% by Volume	% by Occurrence	% by Volume	% by Occurrence
Bass	53.0	71.0	18.0	30.0
Crappie	27.0	30.0	2.5	8.0
Sunfish	7.0	16.0	3.5	6.0
Sub-total	87.0	Aver. 87.0	Sub-tot. 24.0	Aver. 38.0
Non-Game Fish				
Gizzard Shad	5.0	30.0	54.0	78.0
Carp	8.0	30.0	22.0	44.0
Sub-total	13.0	Aver. 50.0	Sub-tot. 76.0	Aver. 88.0
Total	100.0		100.0	

Fully fed mergansers often cannot fly, except that the wind helps them materially in getting off the water. When frightened they try to fly and to make more sure of success, they disgorge the contents of their gullets. Below is a comparison of the contents of:

	74 Flight Birds		50 Non-Flyers	
Game Fish	% by Volume	% by Occurrence	% by Volume	% by Occurrence
Bass	40.0	57.0	30.0	48.0
Crappie	8.0	12.0	20.0	24.0
Sunfish	6.0	15.0	3.0	4.0
Sub-totals	54.0		53.0	
Non-Game Fish				
Gizzard shad	32.0	51.0	31.0	62.0
Carp	14.0	42.0	16.0	38.0
Sub-totals	46.0		47.0	
Totals	100.00		100.00	

The Sperry report estimated a winter population of three thousand mergansers on the lake in 1937-38, and specifically says that this estimate does not discredit estimates of fifteen thousand made by others for other years. Sperry discusses their feeding habits and concludes that, "very few mergansers frequent the south end of the lake at any time during the winter." He thinks that the majority of the mergansers wintering at the lake get one big meal (or its equivalent in two or more feedings) each twenty-four hours. The majority of the bass consumed were from four to six inches long, and the largest found inside a merganser was twelve inches long. Sperry reports one merganser with thirty-six two-inch shad in its gullet and the remains of eighty-seven others of similar size in its stomach. Third place in the diet of mergansers at the lake is taken by carp. Crappie are less frequently captured but those taken are larger in size. Attempts to capture mergansers by means of fish net traps were unsuccessful.

The concluding paragraph of the Sperry report reads, "Consequently it is believed that a big reduction in the merganser population wintering at Elephant Butte Lake would be a great aid to game fish conservation in that section. Such a move would be far more effective than planting fish from the large bass hatchery now under construction below the Elephant Butte dam."

Effective July 14, 1938, and running until June 30, 1939, a permit to kill mergansers on the Elephant Butte Reservoir was issued by the U. S. Biological Survey, Ira N. Gabrielson, chief, to Hugh Boyd. To this permit were these restrictions, "No such bird shall be killed . . . except when committing or about to commit serious injury to such fish," and "Mergansers authorized to be killed hereunder shall not be shot or killed (1) from any blind, sink, pit, or any other device or means of concealment, whether natural or artificial, movable or stationary, or on land or water; (2)[12] and

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[12] Pertains to kind of guns which may be used.

(3) by use of decoys of any description, or traps or nets of any kind.

On July 28, 1938, State Game Warden Elliott S. Barker commented by letter on the merganser situation to the chief of the U. S. Biological Survey, as follows:

> I do not know what action the Bureau contemplates taking toward the necessary reduction of the mergansers at Elephant Butte Lake and elsewhere[13] in the state. However, if the permit to kill mergansers on Elephant Butte Lake, issued to Hugh Boyd, is the only action contemplated, your attention is called to the fact that this action is wholly inadequate to cope with the situation. No one man can possibly control the mergansers on Elephant Butte Lake even if given an absolutely free hand to use every possible method that could be placed at his command. With the drastic restrictions contained in the above mentioned permit . . . I doubt seriously if it would be possible for Mr. Boyd to take 5 per cent of the mergansers on the lake during the winter period if he spent all his time on the project . . . Our recommendation is that all restrictions on the killing of mergansers as to season and bag limit be removed so that the sportsmen themselves may have a free hand in reducing the population and breaking up these terrible concentrations.

In the early part of September, 1938, the merganser situation in New Mexico,[14] and elsewhere, was discussed at a meeting of the Western Association of Fish and Game Wardens, held at Yellowstone Park. Dr. Gabrielson, chief of the U. S. Biological Survey; D. A. Gilchrist, regional director; and W. E. Crouch, of the Washington office, were present. State Game Warden Barker[15] has informed the author that Mr. Gilchrist is cognizant of the situation and has covered it with Dr. Gabrielson, and that an amended permit to relieve the situation would soon be issued. Mr. Barker quoted Mr. Crouch as follows, "I will see to it personally that you get a permit for the control of mergansers on Elephant Butte Lake that will meet your requirements and permit you to make the reduction recommended by Mr. Sperry. We will make the permit in such a manner that the assistance of a reasonable, but limited, number of reliable sportsmen may be enlisted."

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[13] "We should not lose sight of the fact that the merganser situation in the southeastern part of the state, that is, the lower Pecos Valley, is just as acute as it is at Elephant Butte Lake," E. S. Barker, July 28, 1938.

[14] One can conclude from the data and other information given above that *in this particular body of water, namely the Elephant Butte Reservoir,* the performance of the merganser during the long, moderately warm winters of New Mexico, leaves little to be said in his favor. Here during winter there exists a striking unbalance of nature. *Wild Life Research and Management Leaflet* BS-83, issued in May, 1937, by the United States Biological Survey, speaks less harshly of the American merganser and somewhat kindly of the red breasted merganser and the hooded merganser. Data quoted in the leaflet were obtained from birds shot in northern waters, particularly trout streams in Canada and Michigan.

With the stopping of the enormous loss of game fish at Elephant Butte, and with increased stocking from the hatchery below the dam, fishing in the lake should improve greatly, and more sportsmen will spend their vacations there. Indirectly this should improve fishing throughout the state, not only through the elimination of fish-eating ducks, but by relieving the pressure of fishing on the smaller lakes and mountain streams.

SUMMARY

The most recent work upon the lake was done by Greenbank and Barker, and the following general picture and summary of the conditions observed are taken from Greenbank's study, except where birds are discussed. Here Sperry is requoted:

Physical and Chemical

In general, the physical and chemical conditions of the water of Elephant Butte Reservoir are fairly favorable to the growth of fish.

1. *Water level fluctuations.*—There is a rather serious hindrance offered to the spawning of bass by the great changes in the water level of the reservoir. Much of this fluctuation occurs during the spawning season of the bass.

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[15] Letter of September 9, 1938. (This bulletin was printed September 29, 1938.)

Also, the shore-line and shoals vegetation, which is desirable from the standpoint of fish culture, is reduced to a minimum by the water level fluctuation.

2. *Bottom covering.*—Silting and the shifting of silt probably interfere seriously with the production of bottom organisms. On the other hand, the detritus that is brought into the reservoir with the silt, perhaps tends to increase somewhat the richness of the organic matter of the reservoir.

3. The relatively low transparency of the water of the reservoir has an adverse, but not an entirely devastating, effect upon plankton production.

4. *Temperatures.*—Water temperatures, the year around, are quite suitable for warm-weather species of fish. In the late summer, the water temperature (at least in the upper layers of water) tends to become too high for cold-water species, such as trout.

5. *Hydrogen ion concentration; alkalinity; carbon dioxide.*—The water of the reservoir maintains, during the entire year, a pH which is favorable not only to the fish themselves, but to the production of various kinds of fish food as well. Free carbon dioxide was never found to be excessively high, and for a part of the year was entirely absent.

6. *Dissolved oxygen.*—At any time during the year, there is sufficient dissolved oxygen in the upper layer of water to sustain fish life, since the action of wind keeps the upper layers well stirred up. Also, throughout most of the year, even the water near the bottom is fairly well supplied with dissolved oxygen; but in the late summer the lower water becomes somewhat deficient in dissolved oxygen. On September 14, 1935, the bottom water at the one-hundred-foot level (station 1) was almost entirely devoid of dissolved oxygen, as also was the water at the seventy-five-foot depth.

At the same time, the water from the fifty-foot-depth to the surface contained sufficient dissolved oxygen to meet the demands of fish. This upper water, therefore, was in a condition to sustain the fish of the warm-water species. However, this upper water was so warm (73°F. or warmer) as to be almost above the tolerance limit for trout. Therefore, at that time, there was no water in the reservoir, deep or shallow, that was entirely suitable for trout (although perhaps the conditions were not absolutely intolerable). It is likely, also, that conditions in this regard may be even worse in late August, and that they were worse during some of the recent summers of extreme heat and drouth. Therefore, the trout and salmon that were planted in the reservoir a few years ago probably encountered conditions too severe for their survival.

Biological

1. *Shore and shoals vegetation.*—The scarcity of shore and shoals vegetation is regrettable, from the standpoint of fish culture, for it means a scarcity of some of the types of fish food, as well as of shelter for young fish and spawning fish.

2. *Plankton.*—The plankton is rather small in amount as compared with that of many bodies of water, and the fish food is diminished thereby. Yet there is sufficient plankton to help maintain a very large population of gizzard shad and to provide a large amount of food for many young fish.

3. *Bottom organisms.*—The bottom organisms, and other small non-plankton animals, are very scarce in the reservoir, especially as compared with those of most natural lakes. This scarcity probably constitutes the weakest link in the chain of fish food in the reservoir; for this type of food is needed badly by those young fish (particularly of the carnivorous species) that are not large enough to eat smaller fish.

Fish

1. *Forage fish.*—There is an abundance of food for the adult game fish in the millions of gizzard shad that abound in the reservoir. Probably the young of the carp, carp sucker, and buffalo also furnish food for the game fish.

2. *Game fish.*—The bass appeared to be in good condition and of good size. Their growth rate in the reservoir compares fairly well with that in other waters. The crappie and yellow perch in the reservoir furnish fairly good supplementary fishing. The catfish, although they can hardly be considered to be a game fish, contribute very much to the amount of food that is taken from the reservoir.

3. *Parasites.*—Fish parasites, although present in some number, may not be causing much damage to the fish. Fish containing parasites were examined, and except for the parasites appeared to be quite healthy otherwise.

Birds

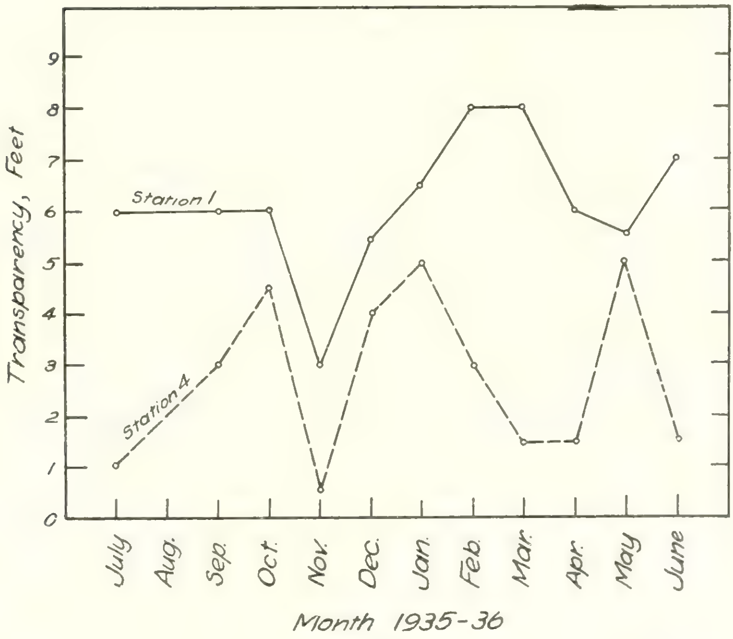
Damage to game fish by fish-eating birds, aside from the mergansers, was not evidenced to any considerable extent by the results of Greenbank's and Barker's survey. However, there were too few specimens of cormorants killed to justify any hard and fast conclusions in this regard.

It must be remembered, however, that cormorants eat whatever fish are most easily captured, and the ones most easy to catch often are shad, which usually are near the surface. Also, during part of the year during which the study was made, the cormorant population of the reservoir was not very large. On the whole, probably not a very great amount of damage is done to the game fish of the reservoir by the cormorants. We must remember, however, that their numbers are increasing.

The gulls of the reservoir apparently feed largely upon shad, most of which, probably, are picked up dead.

The writer, from observation of mergansers below the lake during a part of each winter for the past fifteen years, was not surprised that Sperry ended his report by saying, "Consequently it is believed that a big reduction in the merganser population wintering at Elephant Butte Lake would be a great aid to game fish conservation in that section. Such a move would be far more effective than planting fish from the large bass hatchery now under construction below the Elephant Butte Dam." It seems that permission to control adequately this most adverse factor is soon to be granted.

APPENDIX



GRAPH 1 (Greenbank)

TRANSPARENCY, VARIATION WITH MONTH

This graph shows water transparency at two stations, where data were secured. It can readily be seen that the water is less transparent at Station 4. This is toward the head of the lake.

TABLE I (By Greenbank)

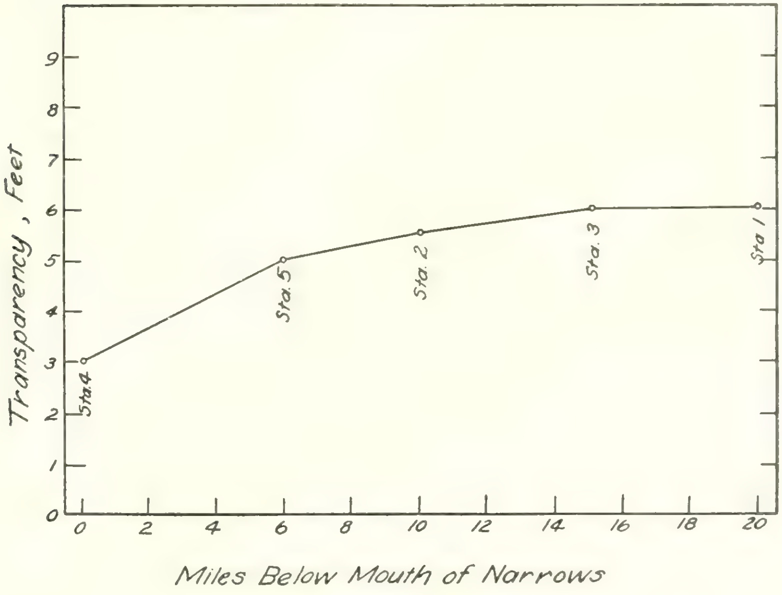
PHYSICAL DATA

This table shows depth, transparency, air and water temperatures, and bottom types at the different stations where data were collected.

Station No.	1935-36			Weather	Total Depth Feet	Tran. Feet	Air Temp. °F	Surf. Temp. °F	Bottom Type
	Month	Day	Hour						
1	June	24	3P		94	6	93.9	77.0	Silt
	July	10	9A		105	6	88.5	79.7	Silt
	Sept.	14	9A	Clear	95	6	102.0	74.8	Silt
	Oct.	13	11A	Clear	95	6	72.0	68.8	Brown silt
	Nov.	8	4P	Wind	93	3	64.6	60.1	Brown silt
	Dec.	8	2P	Clear	93	5½	51.4	54.0	Tan silt
	Jan.	2	4P	Clear	100	6½	52.3	48.7	Brown silt
	Feb.	4	11A	Clear	100	8	41.5	45.3	Tan silt
	Mar.	5	2P	Dusty	102	8	70.3	51.8	Tan silt
	Apr.	6	3P	Clear	99	6	59.0	51.6	Tan silt
	May	3	1P	Pt. Cd.	105	5½	86.5	68.0	Tan silt
	June	7	10A	Clear	109	7	75.9	69.8	Soft silt
2	June	28	11A		68	3	87.1	77.9	Silt
	July	11	8A		78	4	86.9	79.5	Silt
	Sept.	14	3P	Clear	78	4	90.0	76.8	Brown silt
	Oct.	13	8A	Clear	72	7	61.5	69.8	Tan silt
	Nov.	9	1P	Wind	71	3	69.1	59.4	Thin silt
	Dec.	8	10A	Clear	74	7½	42.4	52.2	Tan silt
	Jan.	4	10A	Cloudy	75	6	35.4	44.4	Silt
	Feb.								
	Mar.	6	12N	Clear	79	7	58.6	52.2	Silt
	Apr.								
	May	2	1P	Pt. Cd.	87	6	77.5	65.8	Tan silt
	June	6	5P	Clear	84	4	77.4	71.8	Soft silt
3	June	26	10A		25	4½	83.5	75.9	Gravel
	Sept.	14	5P	Pt. Cd.	40	4	79.5	77.4	Black silt
	Oct.	13	10A	Clear	37	5	65.5	69.8	Sand
	Nov.	9	11A	Wind	42	3½	54.7	59.0	Gravel
	Dec.	8	12N	Clear	35	7½	54.0	53.6	Sand
	Jan.	4	12N	Pt. Cd.	45	7	41.0	46.8	Gravel
	Feb.	4	9A	Cloudy	48	5	35.4	45.3	Gravel
	Mar.	6	5P	Clear	41	7	52.5	51.1	Sand
	Apr.	6	2P	Clear	34	7	57.2	51.6	Gravel
	May	3	11A	Clear	43	8	82.4	66.6	Gravel
	June	7	7A	Clear	57	5	63.1	68.0	Mud
4	July	8	9A		16	1	79.2	78.8	Silt
	Sept.	15	10A	Clear	14	3	80.4	77.2	Tan silt
	Oct.	13	11A	Clear	14	4½	74.8	71.1	Brown mud
	Nov.	11	8A	Wind	16	½	39.9	51.4	Silt
	Dec.	7	12N	Clear	16	4	50.7	50.7	Silt
	Jan.	3	11A	Cloudy	18	5	45.5	43.5	Tan silt
	Feb.	2	10A	Cloudy	21	3	50.9	44.2	Tan silt
	Mar.	7	4P	Pt. Cd.	23	1½	59.7	55.0	Tan silt
	Apr.	5	3P	Clear	23	1½	80.8	57.6	Tan silt
	May	2	5P	Clear	26	5	67.5	66.9	Tan silt
	June	6	10A	Clear	28	1½	68.7	71.4	Thin silt

TABLE I
PHYSICAL DATA (Continued)

Station No.	1935-36 Month	Day	Hour	Weather	Total Depth Feet	Tran. Feet	Air Temp. °F	Surf. Temp. °F	Bottom Type
5	July	6	11A		64	3	85.6	78.6	Gravel
	Sept.	15	11A	Clear	51		86.2	77.9	Tan silt
	Oct.	12	2P	Wind	51	7	73.6	71.6	Tan silt
	Nov.	9	4P	Wind	51	3	61.2	58.6	Thin silt
	Dec.	7	4P	Clear	54	7	51.8	52.9	Brown silt
	Jan.	4	8A	Cloudy	56	4	28.9	43.5	Tan silt
	Feb.	4	7A	Cloudy	57	4½	36.5	43.9	Tan silt
	Mar.	6	10A	Hazy	59	4	55.4	50.7	Tan silt
	Apr.								
	May	2	3P	Clear	63	5	77.7	68.7	Tan silt
	June	5	3P	Clear	67	5	76.6	75.2	Tan silt
6	July	2	2P		37	1	85.3	76.5	Silt
	Sept.								
	Oct.	12	11A	Wind	20	5	72.9	71.4	Mud
	Nov.								
	Dec.	7	2P	Clear	20	7	51.8	51.8	Black silt
	Jan.	3	12N	Cloudy	21	4½	46.0	45.3	Tan silt
	Feb.	2	12N	Cloudy	24	4	50.0	44.8	Black silt
	Mar.	7	1P	Clear	24	5	60.4	54.7	Brown silt
	Apr.	5	4P	Pt. Cd.	27	3	56.3	53.8	Brown silt
	May	2	4P	Clear	27	8	77.0	67.1	Tan silt
	June	5	4P	Clear	32	3	76.3	71.6	Gummy silt



GRAPH 2 (Greenbank)

TRANSPARENCY, VARIATION WITH DISTANCE

This graph shows the general tendency of the silt to settle, leaving the water more clear as it goes from the head of the lake toward the dam.

TABLE II (By Greenbank)

TEMPERATURES, FAHRENHEIT

Ten months' record of air and water temperatures at various depths, at six stations where data were collected.

STATION 1

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	14	13	8	8	2	4	5	6	3	7
Hour	9A	11A	4P	2P	4P	11A	2P	3P	1P	10A
Depth	95	95	93	93	100	100	102	99	105	109
Air	102	72.0	64.6	51.4	52.3	41.5	70.3	59.0	86.5	75.9
Surface	74.8	69.8	60.1	54.0	48.7	45.3	51.8	51.6	68.0	69.8
1 ft.	74.8	70.7	60.1	54.0	48.6	45.9	51.1	51.3	67.8	67.6
5 ft.	74.1	69.6	60.1	54.0	48.6	45.7	51.1	51.1	62.6	67.1
10 ft.	74.1	69.4	60.1	53.8	48.4	45.3	49.6	50.9	62.2	66.9
15 ft.	74.1	69.1	60.1	53.4	48.2	45.3	48.9	50.9	62.1	66.6
20 ft.	73.9	69.1	60.1	53.4	48.2	45.3	48.2	50.9	61.3	66.2
25 ft.		69.3	60.1	53.2	48.2	45.3	47.8	50.7	61.0	66.2
30 ft.	74.1	69.3	60.1	53.2	48.2	45.3	47.7	50.4	59.7	66.0
40 ft.	74.1	69.4	60.1	53.2	48.2	45.1	47.8	50.2	58.5	65.5
50 ft.	73.4	69.1	60.1	53.2	48.2	45.1	47.3	50.2	57.2	61.3
60 ft.	70.9	69.1	59.9	53.2	48.2	45.3	47.1	50.2	53.2	59.5
70 ft.	69.4	68.0	59.9	53.1	48.2	45.3	47.1	50.2	52.2	57.6
80 ft.	69.3	67.3	57.9	53.1	48.2	45.3	46.9	50.2	51.8	56.1
90 ft.	68.9	—	—	—	48.2	45.3	46.8	50.2	51.8	55.4
100 ft.					48.0	45.3	—		51.6	54.9
Bottom	68.4	66.6	57.9	53.1	48.0	45.3	46.8	50.2	51.6	54.5

STATION 2

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	14	13	9	8	4	—	6	—	2	6
Hour	3P	8A	1P	10A	10A	—	12N	—	1P	5P
Depth	78	72	71	74	75	—	79	—	87	84
Air	90.0	61.5	69.1	42.4	35.4	—	58.6	—	77.5	77.4
Surface	76.6	69.8	59.4	52.2	44.4	—	52.2	—	65.8	71.8
1 ft.	76.5	69.7	59.4	52.2	46.2	—	51.4	—	65.1	71.8
5 ft.	75.2	69.8	59.2	52.2	46.2	—	51.1	—	63.9	71.6
10 ft.	74.8	69.4	58.8	52.2	46.2	—	50.0	—	63.3	68.7
15 ft.	74.8	69.7	58.8	52.2	46.2	—	49.6	—	62.4	67.6
20 ft.	74.5	69.7	58.8	52.2	46.2	—	49.1	—	62.1	66.9
25 ft.	—	69.4	58.6	52.2	46.2	—	48.9	—	61.2	66.9
30 ft.	74.1	69.4	58.6	51.8	46.2	—	48.6	—	61.0	66.6
40 ft.	73.9	69.4	58.6	51.1	46.2	—	47.8	—	59.0	66.2
50 ft.	73.8	69.1	58.6	50.7	46.2	—	47.7	—	54.0	62.4
60 ft.	72.1	68.2	58.3	50.5	46.2	—	47.5	—	52.9	57.7
70 ft.	—	67.6	56.5	50.2	46.0	—	47.5	—	52.2	56.3
80 ft.									52.0	—
Bottom	71.1	67.6	56.5	50.2	46.0	—	47.3	—	52.0	56.3

TABLE II

TEMPERATURES, FAHRENHEIT (Continued)

STATION 3

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	14	13	9	8	4	4	5	6	3	7
Hour	5P	10A	11A	12N	12N	9A	5P	3P	11A	7A
Depth	40	37	42	35	45	48	41	33	43	57
Air	79.5	65.5	54.7	54.0	41.0	35.4	52.5	57.2	82.4	63.1
Surface	77.4	69.8	59.0	53.6	46.8	45.3	51.1	51.6	66.6	68.0
1 ft.	77.4	69.8	59.0	53.6	46.9	45.3	50.7	51.3	65.7	68.0
5 ft.	77.4	69.8	59.0	52.9	46.8	45.3	50.5	51.1	63.5	68.0
10 ft.	76.6	69.8	59.0	52.7	46.8	45.5	50.0	50.9	63.0	67.8
15 ft.	74.5	69.8	59.0	52.5	46.8	45.5	49.5	50.7	62.8	67.6
20 ft.	74.5	69.8	59.0	52.5	46.8	45.5	48.9	50.7	61.5	67.5
25 ft.	—	69.4	59.0	52.5	46.8	45.7	48.2	50.5	60.3	67.1
30 ft.	74.1	69.4	—	—	46.6	45.3	48.0	50.5	60.1	65.8
40 ft.	73.9		58.6		46.6	45.3	47.7		58.5	64.9
Bottom	73.9	69.4	—	52.3	46.6	45.3	47.7	50.5	58.5	59.5

STATION 4

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	15	12	11	7	3	2	7	5	2	6
Hour	10A	11A	8A	12N	11A	10A	4P	3P	5P	10A
Depth	14	14	16	16	18	21	23	23	26	28
Air	80.4	74.8	39.9	50.7	45.5	50.9	59.7	80.8	67.5	68.7
Surface	77.2	71.1	51.4	50.7	43.5	44.2	55.0	57.6	66.9	71.4
1 ft.	77.0	70.9	51.8	50.4	43.5	44.2	53.2	53.8	66.9	71.6
5 ft.	76.5	70.9	51.8	50.0	43.3	44.2	51.4	53.2	66.0	70.9
10 ft.	76.3	68.9	50.9	50.0	42.3	43.9	50.0	52.9	64.8	69.8
15 ft.			50.9	48.6	41.7	43.5	49.6	52.9	64.2	69.8
20 ft.						43.5	49.6	52.9	63.3	69.6
Bottom	76.6	65.1	50.9	48.6	41.0	43.5	49.6	52.9	63.0	62.7

TABLE II
TEMPERATURES, FAHRENHEIT (Continued)

STATION 5

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	15	12	9	7	4	4	6	—	2	5
Hour	11A	2P	4P	4P	8A	7A	10A	—	3P	3P
Depth	51	51	51	54	56	57	59	—	63	67
Air	86.2	73.6	61.2	51.8	28.9	36.5	55.4	—	77.7	76.6
Surface	77.9	71.6	58.6	52.9	43.5	43.9	50.7	—	68.7	75.2
1 ft.	77.4	71.6	58.6	52.7	45.0	44.2	50.4	—	68.4	74.7
5 ft.	75.6	71.6	58.6	52.5	45.3	44.2	50.0	—	64.4	69.3
10 ft.	75.0	70.9	58.3	52.2	45.3	44.2	49.6	—	63.0	68.5
15 ft.	74.8	70.9	58.3	51.4	45.3	44.2	49.5	—	62.8	68.0
20 ft.	74.7	70.5	57.9	51.4	45.3	44.2	49.3	—	62.1	68.0
25 ft.	—	70.2	57.9	51.1	45.3	44.2	49.1	—	61.7	68.0
30 ft.	74.5	70.2	57.9	50.7	45.3	44.2	48.9	—	60.8	68.0
40 ft.	74.1	69.8	57.9	50.2	45.3	44.2	48.2	—	58.3	67.1
50 ft.	73.9	69.4	57.9	—	45.3	44.2	47.8	—	55.0	60.4
60 ft.								—	—	58.1
Bottom	73.9	69.4	57.9	49.8	45.3	44.2	47.7	—	52.7	56.8

STATION 6

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Day	—	12	—	7	3	2	7	5	2	5
Hour	–	11A	—	2P	12N	12N	1P	4P	4P	4P
Depth	—	20	—	20	21	24	24	27	27	32
Air	—	72.9	—	51.8	46.0	50.0	60.4	56.3	77.0	76.3
Surface	—	71.4	—	51.8	45.3	44.8	54.7	53.8	67.1	71.6
1 ft.	—	71.2	—	51.8	45.3	44.2	52.2	53.7	65.7	71.4
5 ft.	—	71.2	—	51.1	45.0	44.1	50.4	52.5	64.0	71.1
10 ft.	—	70.9	—	50.7	45.0	43.9	49.6	52.5	63.9	71.1
15 ft.	—	70.7	—	50.7	45.0	43.7	49.3	52.3	62.9	70.9
20 ft.	—		—		45.0	43.5	49.3	52.3	62.8	69.6
25 ft.	—		—					53.2	—	69.3
Bottom	—	70.2	—	50.4	45.0	43.5	49.3	52.2	60.1	69.1

TABLE III

(By Greenbank)

CHEMICAL DATA

Station No.	1935-36 Month	Day	Hour	Samp. Depth Feet	Samp. Temp. °C	pH	CO_2 ppm	Phe. Alk. ppm	M. O. Alk. ppm	O_2 ppm
1	June	24	3P	93	15.2	7.0	2.0	0	155	6.3
	July	10	9A	104	15.9	7.4	9.0	0	148	2.2
	Sept.	14	9A	93	20.2	—	3.5	0	136	0.6
	Oct.	13	11A	94	19.2	8.0	3.0	0	110	3.8
	Nov.	8	4P	92	14.4	8.4	None	6	116	6.9
	Dec.	8	2P	93	11.7	8.2	None	5	115	7.3
	Jan.	2	4P	99	8.9	8.4	None	7	124	8.5
	Feb.	4	11A	99	7.4	8.6	None	10	125	9.0
	Mar.	5	2P	100	8.2	8.6	None	11	133	9.2
	Apr.	6	3P	98	10.1	8.2	None	11	131	9.2
	May	3	1P	104	10.9	8.4	None	10	134	8.0
	June	7	10A	108	12.5	8.2	2.0	0	144	5.7
1a	Sept.	14	9A	75	20.8	—	5.0	0	121	0.6
	Oct.	13	11A	75	19.8	8.2	3.0	0	114	3.2
	Nov.	8	4P	75	15.0	8.2	None	4	118	7.1
	Dec.	8	2P	75	11.7	8.2	None	6	115	7.7
	Jan.	2	4P	75	9.0	8.4	None	5	122	8.5
	Feb.	4	11A	75	7.4	8.6	None	7	125	9.2
	Mar.	5	2P	75	8.3	8.6	None	6	131	8.9
	Apr.	6	3P	75	10.1	8.4	None	11	130	9.2
	May	3	1P	75	11.2	8.4	None	7	130	8.1
	June	7	10A	75	13.8	8.2	None	2	140	6.0
1b	Sept.	14	9A	50	23.0	—	3.0	0	110	2.7
	Oct.	13	11A	50	20.6	8.2	1.0	0	113	4.3
	Nov.	8	4P	50	15.6	8.2	None	1	114	7.2
	Dec.	8	2P	50	11.8	8.4	None	4	114	7.6
	Jan.	2	4P	50	9.0	8.4	None	5	122	8.5
	Feb.	4	11A	50	7.3	8.6	None	7	127	9.1
	Mar.	5	2P	50	8.5	8.6	None	10	129	9.1
	Apr.	6	3P	50	10.1	8.4	None	8	130	8.8
	May	3	1P	50	14.0	8.4	None	12	135	8.4
	June	7	10A	50	16.3	8.2	None	2	132	6.3
1c	Sept.	14	9A	30	23.4	—	1.5	0	109	4.5
	Oct.	13	11A	30	20.7	8.2	0.5	0	113	4.6
	Nov.	8	4P	30	15.6	8.4	None	3	113	7.4
	Dec.	8	2P	30	11.8	8.2	None	8	118	7.6
	Jan.	2	4P	30	9.0	8.6	None	6	119	8.6
	Feb.	4	11A	30	7.4	8.6	None	9	128	9.3
	Mar.	5	2P	30	8.7	8.6	None	10	129	9.2
	Apr.	6	3P	30	10.2	8.4	None	8	132	8.9
	May	3	1P	30	15.4	8.6	None	11	135	8.8
	June	7	10A	30	18.9	8.4	None	7	130	7.4
2	June	28	11A	67	16.0	7.4	2.5	0	140	3.9
	July	11	8A	77	16.3	7.4	3.5	0	143	2.3
	Sept.	14	3P	75	20.7	—	6.5	0	127	1.2
	Oct.	13	8A	71	19.8	8.0	0.5	0	111	3.8
	Nov.	9	1P	70	13.6	—	None	4	124	7.4
	Dec.	8	10A	73	10.1	8.4	None	7	121	8.1

TABLE III

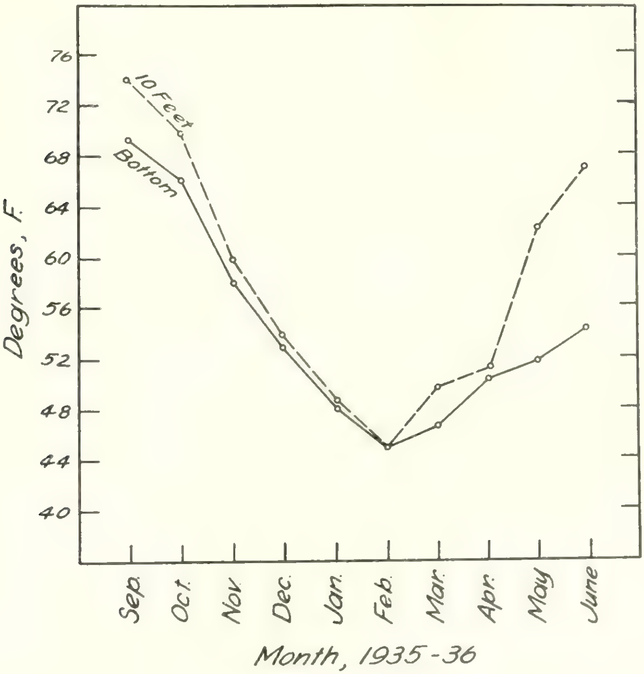
CHEMICAL DATA (Continued)

Station No.	1935-36 Month	Day	Hour	Samp. Depth Feet	Samp. Temp. °C	pH	CO₂ ppm	Phe. Alk. ppm	M. O. Alk. ppm	O₂ ppm
	Jan.	4	10A	74	7.8	8.6	None	9	128	9.0
	Feb.	—	—	—	—	—	—	—	—	—
	Mar.	6	12N	78	8.5	8.6	None	11	130	9.0
	Apr.	—	—	—	—	—	—	—	—	—
	May	2	1P	85	11.1	8.2	None	10	138	7.9
	June	6	5P	83	13.5	8.2	1.0	0	148	5.2
2a	June	28	11A	50	18.5	7.6	1.0	0	128	5.2
	Sept.	14	3P	50	23.2	—	None	5	109	5.4
	Oct.	13	8A	50	20.6	8.2	None	5	108	6.0
	Nov.	9	1P	50	14.8	—	None	4	121	7.5
	Dec.	8	10A	50	10.4	8.4	None	6	118	8.1
	Jan.	4	10A	50	7.9	8.6	None	8	127	8.9
	Feb.	—	—	—	—	—	—	—	—	—
	Mar.	6	12N	50	8.7	8.6	None	8	131	9.2
	Apr.	—	—	—	—	—	—	—	—	—
	May	2	1P	50	12.2	8.4	None	7	133	8.2
	June	6	5P	50	16.9	8.2	None	0	129	5.8
3	June	26	10A	24	22.0	7.6	None	5	122	5.9
	Sept.	14	5P	40	22.3	—	None	5	109	4.3
	Oct.	13	10A	36	20.8	8.8	None	5	109	6.2
	Nov.	9	11A	40	14.8	8.4	None	4	118	7.5
	Dec.	8	12N	34	11.3	8.4	None	5	115	7.8
	Jan.	4	12N	44	8.1	8.6	None	10	124	9.4
	Feb.	4	9A	47	7.4	8.6	None	7	125	9.5
	Mar.	6	5P	40	8.7	8.6	None	12	132	9.5
	Apr.	6	2P	33	10.3	8.4	None	6	135	9.4
	May	3	11A	41	14.7	8.4	None	8	137	8.3
	June	7	7A	55	15.3	8.2	None	3	132	5.6
4	July	8	9A	15	24.2	7.6	1.0	0	111	5.7
	Sept.	15	10A	13	24.8		None	9	108	7.5
	Oct.	12	11A	13	18.4	8.4	None	6	124	7.6
	Nov.	11	8A	15	10.5	—	None	6	121	8.5
	Dec.	7	12N	15	9.4	8.4	None	7	115	9.8
	Jan.	3	11A	17	5.0	8.4	None	11	145	10.5
	Feb.	2	10A	20	6.4	8.6	None	10	151	9.4
	Mar.	7	4P	22	9.8	8.6	None	12	152	8.7
	Apr.	5	3P	22	11.6	8.4	None	11	148	9.0
	May	2	5P	24	17.2	8.2	None	0	121	6.8
	June	6	10A	27	20.4	8.2	None	5	122	6.3
5	July	6	11A	64	17.3	7.4	7.0	0	145	2.8
	Sept.	15	11A	50	23.3	—	None	5	108	5.0
	Oct.	12	2P	50	20.8	8.2	None	5	106	5.7
	Nov.	9	4P	50	14.4	—	None	6	121	7.5
	Dec.	7	4P	53	9.9	8.4	None	7	116	8.0
	Jan.	4	8A	55	7.4	—	None	8	130	9.5
	Feb.	4	7A	56	6.8	8.6	None	6	130	9.5
	Mar.	6	10A	57	8.7	8.6	None	7	133	9.4
	Apr.	—	—	—	—	—	—	—	—	—

Table III

CHEMICAL DATA (Continued)

Station No.	1935-36 Month	Day	Hour	Samp. Depth Feet	Samp. Temp. °C	pH	CO_2 ppm	Phe. Alk. ppm	M. O. Alk. ppm	O_2 ppm
	May	2	3P	60	11.8	8.2	None	8	141	7.5
	June	5	3P	65	13.8	8.2	2.0	0	138	4.8
6	July	2	2P	36	23.1	7.6	1.0	0	119	6.5
	Sept.	—	—	—	—	—	—	—	—	—
	Oct.	12	11A	19	21.4	8.4	None	7	109	6.4
	Nov.	—	—	—	—	—	—	—	—	—
	Dec.	7	2P	19	10.2	8.4	None	10	110	8.4
	Jan.	3	12N	20	7.2	8.6	None	7	131	9.5
	Feb.	2	12N	23	6.4	8.6	None	8	134	9.8
	Mar.	7	1P	23	9.6	8.6	None	20	138	9.1
	Apr.	5	4P	26	11.2	8.4	None	7	—	8.9
	May	2	4P	25	15.6	8.2	None	10	128	7.3
	June	5	4P	30	20.6	8.4	None	5	120	6.8



GRAPH 3 (Greenbank)

Temperature, Variation With Month

Ten months' record of varying water temperatures at depths of ten feet and at the bottom, at the sampling station nearest the dam.

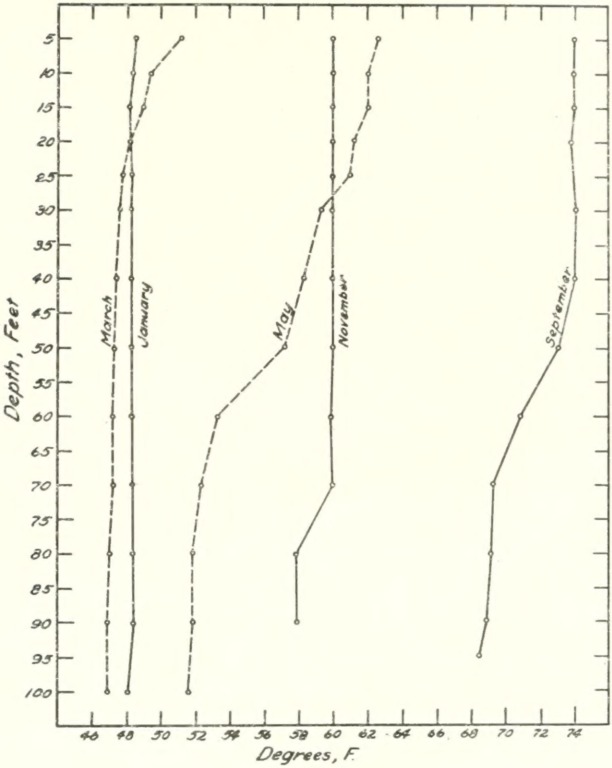
Table IV

(By Hazzard)

GROWTH RATE STUDIES OF FISHES

How rapidly fish have been found to grow in Elephant Butte Reservoir.

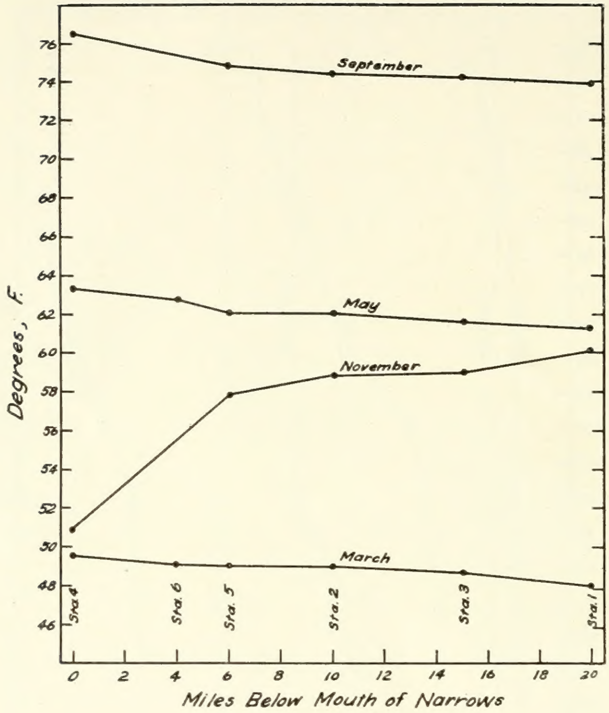
Species	Age, Years	Number of Fish Averaged	Average Length, Inches	Average Weight Ounces
Bass	0	41	2	—
	2	8	12	15.1
	3	1	16	24.0
	4	1	18	41.3
	5	1	21	64.0
Crappie	0	6	3	—
	1	20	5	1.2
	2	5	7	2.4
	3	2	9	4.6
Yellow Perch	0	12	2	—
	1	11	5	0.9
	2	2	11	7.5
	3	5	10	8.1
Bluegill	1	1	4	0.7
	2	7	4	0.6
	3	1	6	2.7
	4	1	6	2.5
Gizzard Shad	0	(7)	2	—
	1	1	5	0.7
	2	9	6	1.3
	3	24	7	2.5
	4	7	9	3.9
	5	6	9	4.5
Carp	1	2	5	1.4
	2	1	8	3.7
	3	4	9	4.7
	4	3	9	6.1
	5	4	11	7.3
Carp Sucker	1	2	12	11.8
	2	20	13	16.8
	3	11	12	13.2
	5	2	17	30.2



GRAPH 4 (Greenbank)

TEMPERATURE, VARIATION WITH DEPTH

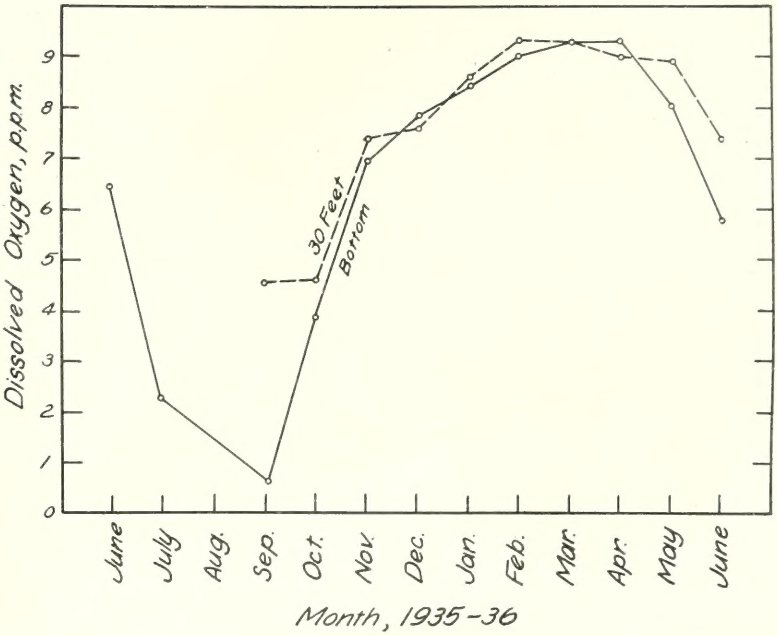
Temperature variations at the sampling station nearest to the dam. In January, little variation between the top and the bottom; in May, wide variation.



GRAPH 5 (Greenbank)

TEMPERATURE, VARIATION WITH DISTANCE

Temperature variations at twenty feet depth, from the Narrows to near the dam. The November curve shows how the more shallow water at the upper part of the lake cools off much faster than the deeper water toward the dam.



GRAPH 6 (Greenbank)

Dissolved Oxygen

This shows the oxygen content of the water in parts per million at the sampling station nearest to the dam. The low content of oxygen at the bottom in late August and early September, is striking.